CM-227
Project 2.10
CZ130

WINDSTAR MANGROVE MITIGATION SITE

FINAL PROGRESS REPORT

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Date: January 3, 1990

Funds for this project were provided by the Department of Environmental Regulation, Office of Coastal Management using funds made available through the National Oceanic and Atmospheric Administration under the Coastal Zone Management Act of 1972, as amended.

EXECUTIVE SUMMARY

FINAL PROGRESS REPORT TO THE STATE OF FLORIDA DEPARTMENT OF ENVIRONMENTAL REGULATION (DER), OFFICE OF COASTAL MANAGEMENT, ON THE INVESTIGATION OF MANGROVE FOREST HABITATS THAT HAVE BEEN CREATED THROUGH MITIGATION.

OBJECTIVE: To provide DER with a final progress report on the investigation of mangrove forest communities that have been created through mitigation at Windstar Resort, on Naples Bay, in Collier County, Florida.

CONSIDERATIONS:

On 01 January, 1989, research was initiated on a comparative study of mangrove forest communities at Windstar Resort, on Naples Bay; this study was designed as part of an ongoing Coastal Zone Management (CZM) coastal management plan for Collier County. The study is designed to compare naturally occurring mangrove habitat with artificially created (planted) mangrove systems; the artificially produced forests were planted by the Windstar Development as mitigation for destruction of habitat during development. The purpose of the research is to obtain data that will contribute to the understanding of the productivity, viability, and practicality of prescribed mitigation efforts in two fundamental areas: 1) the rate of survival and growth of the mangroves that were originally planted seven years before the start of the study; 2) colonization by other plant species in the mitigation sites, and the implications that this may have on succession in mitigated areas. The attached report is a synopsis of work, compiled from the previous 12 months, on the Coastal Zone Management mangrove mitigation research study that has been contracted by Collier County to the Center for Environmental Education, Edison Community College, and Friends of Rookery Bay.

The study compares mitigated forest sites to existing natural areas by collecting and measuring mangrove leaf litter, stem tip growth rates, soil salinity, and macro-invertebrate species composition through the duration of the study. Three principal components that are measured are: 1) extension growth of mangrove stems and production of leaf litter; 2) numbers of replanted and naturally colonizing new mangroves; 3) species composition and numbers of individuals of macro-invertebrates associated with each site. Permanent study stations have been established in the interior of the replanted areas and in the naturally occurring mangrove forest, so that data may be collected at the same locations in the future. Additional data have been gathered on the amounts of herbivory on leaves, abundances of marine macro-fauna, abundances of seagrasses, soil salinities, mangrove species composition within and outside of the mitigation sites, and many other related observations in and around the study areas.

The project has been designed, and study areas have been set up, so that the study may be continued over a long period of time. Sample areas and individual trees have been identified so that investigators will be able to return to the same sample sites, and measurements may be repeated on the same individual tree branches in the future. Comparisons and continuous measurement of individual trees, and their surroundings, will be possible during future studies of the mitigation sites, and their surrounding natural forest systems.

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ACKNOWLEDGMENTS

Many people contributed to making this study possible. Mr. James N. Burch acted as liaison between Collier County and the principal investigators, provided field support (personally and other County staff), arranged for use of the County helicopter on two occasions, designed and constructed litter collecting boxes used in this study, provided expertise in plant identification and spent many hours collecting and measuring length, width, and area of leaves. Dr. Robert Twilley and Ms. Heather Warner of Southwestern Louisiana State University spent a considerable amount of time on the phone and on site (Ms. Warner) teaching us the techniques that they used to mark and measure mangrove stems, and generally discussing with us the sites, project, and data. Field assistance was provided by Mr. Keith Edwards, Ms. Kathryn Muldoon, Ms. Heidi B. Lovett, Ms. Maura Kraus, and Mr. Steven Grabe. Mr. Grabe and Ms. Muldoon also helped identify certian invertebrate taxa collected. Mr. David Crewz of the Florida Marine Research Institute and Mr. James Beever of the Department of Natural Resources Pine Island Aquatic Preserve engaged in numerous useful and informative discussions with us regarding this project and the general topics of mangrove biology and mitigation. Drs. Samuel Snedaker and Eric Heald also provided insights regarding mangrove ecology during valuable discussions. Collier County Forester, Mr. Chris Anderson, provided insight on tree biology and forestry techniques, and allowed us to use equipment as needed. Dr. Kris Thoemke of the Rookery Bay National Estuarine Research Reserve, permitted us to use the drying oven and mettler balances in his facility. Mr. Geoffery Churchill of Mangrove Systems, Inc. (now Proctor and Redfern) and various members of Coastal Engineering Consultants, Inc. provided needed information regarding site preparation and the planting. Most importantly, in a spirit of true cooperation between developers and the conservation community, Mr. Bernard Johnson and Mr. Jack Mac'Kie of Windstar on Naples Bay graciously allowed use of mitigation sites in this development for the studies. The project was funded by a grant from the Department of Environmental Regulation to Collier County.

INTRODUCTION

As coastal wetlands continue to decline due to encroaching civilization, pollution, and possibly rising sea level, concern for their protection concomitantly increases. In addition, as the human population of Florida swells, and with most wanting to live near the coast, the pressure mounts for increased development in, and various other consumptive uses of, coastal wetlands.

Florida has 6,884,900 acres of coastal wetlands of which 1,405,600 are salt marsh, 254,200 are fresh water marsh, and 5,032,100 are "forested scrub-shrub" type dominated primarily by mangroves in estuarine areas and cypress and willow in freshwater sites (Reyer et al. 1988). Other states in the Gulf of Mexico have considerably fewer coastal wetland (acreages are: Louisiana - 3,345,900; Texas - 1,662,500; Alabama - 1,071,600; and Mississippi - 719,700) (Reyer et al. 1988). Of the forested coastal wetland systems, mangroves occupy an estimated 430,000 to 500,000 acres in south Florida (Odum et al. 1982). These, and other coastal and estuarine habitats ranging from salinas (salt barrens) to sea grasses, provide myriad ecological benefits including habitat for thousands of animal species, biological productivity for numerous fishery populations, coastal stabilization, and protection of upland ecosystems from storm surge (Heald 1969, Lugo and Snedaker 1974, Odum 1979, Odum and Heald 1972, Thayer et al. 1987, Tomlinson 1986).

In response to the pressure to allow more and more use of wetlands, federal, state, and local governmental agencies charged with protection of wetlands have had to address two complex and provocative questions. First, can the functions of naturally occurring wetlands be replaced once destroyed by creating new wetlands? Second, should other procedures, for example, removal of noxious exotic plant species, providing conservation easements or deeds to wetlands not targeted for destruction, or re-establishing "historic" hydrological regimes to drained wetlands, be allowed as alternative forms of mitigating the negative effects of wetland loss? This became even more of a focal point for environmental regulators when the President of the United States promised that there would be a "no net wetland loss" policy.

In recent years concern has increased as to whether restoration mitigation typically re-establishes all lost wetland ecological <u>functions</u>, or if projects often simply provide a "garden" of wetland plant species of limited overall ecological value. Although opinions abound on both sides of the question, few detailed studies exist to provide the data necessary to properly formulate an objective answer. Recent publications have documented the status of knowledge (Kusler and Kentula 1989 a,b) and there is some substantive work currently being conducted. For example, the Florida Department of Natural Resources (DNR), Marine Research Institute, in conjunction with Lewis Environmental Services, Inc., have conducted a survey of many mitigation sites of varying age and species composition. The results of this study are currently being reviewed and analyzed by the DNR. The U.S. Environmental Protection Agency, Gulf of Mexico Habitat Evaluation Task Force is surveying wetlands Gulf-wide. The results of this study will be available around April 1990. The National Marine Fisheries Service has on-going projects addressing fish utilization of restored and natural marshes and sea grass restoration.

We have taken a different approach than many of the agency studies. Instead of surveying a broad spectrum of mitigation projects, we chose to focus more in-depth work in one mangrove mitigation project. Our studies are designed to quantitatively assess the following primary questions: (1) How well did the originally-planted mangroves survive and grow over the seven years since they were planted; (2) What other plant species have colonized the sites, and what implications might this have on successional patterns?

We have also gathered quantitative data on the amount of herbivory on leaves, the abundance of marine macrofaunal invertebrates living in the sites, litterfall, the occurrence of cocoons and caterpillars on mangrove leaves, and the species composition of the natural mangrove forest that surrounds the mitigation sites, and soil salinities. Also, we have made qualitative field observations on use of the areas by wading birds, raptors, raccoons, spiders, and fish. The results of these studies and observations will be included in a series of reports on this project.

Our project plots have been set up and marked in such a manner as to allow us, or any other scientist, to conduct similar studies in exactly the same area, and even on many of the same individual plants, in the future. Although funding for this project was provided for only one year, we envision this as a long-term study to evaluate the growth and successional patterns occurring in the site over the course of the development of this plant assemblage. The lead organization in this study, the Center for Marine Conservation, is committed to the study in order to provide data for the development of a model for use by agencies in mangrove wetland policy decisions.

Considerable data on various features of both the mitigation sites and their surrounding natural forest have been gathered. These data will be presented in a series of reports. Here, the project history is documented, the study sites and surrounding natural forest described, and the studies outlined.

PROJECT HISTORY

The development, Windstar on Naples Bay, is a golf course community encompassing some 400 acres on the eastern shores of Naples Bay, in Collier County, Florida. The developer proposed to "recontour" existing tidal wetlands during the ~~creation of the~~ golf course. This resulted in the filling of 5.5 acres of wetlands allowed in Florida Department of Environmental Regulation permit number 11-45104 (issued March 23, 1982, under the project name "Whispering Pines" expired February 30, 1987).

In mitigation for this loss, the developer proposed to recreate 15.4 acres of submerged wetlands from three old, existing spoil mounds (from north to south about 3.30, 7.68, and 4.40 acres) in the mangrove forest of their development. The spoil had apparently been deposited in the mangroves when the channel in Naples Bay was dredged. The mounds were infested with Australian pine (Casurina litorea L., Brazilian pepper (Schinus terebinthifolius Raddi).

The initial mitigation work occurred in August and September of 1982. A small access path was created to each site, the sites were scraped to 0.8 to 1.9 feet NGVD (re-exposing the covered mangrove soils), and planted with pairs of Rhizophora mangle L. propagules on one meter centers (Bradow 1986). About 70,000 propagules were planted. Survival of the plants after 8 months was reportedly 97 % and some "volunteer" colonization by Avicennia germinans (L.) Stearn had occurred in portions of the sites (Stephen 1984).

According to Bradow (1986) none of the propagules planted below 1.0 foot NGVD survived the first year. He cites that, this lead to the establishment of about 2 acres of "open mud flats".

After 3.5 years, Bradow (1986) reports the survival of red mangroves to be 85 %, with many of the red mangroves reaching heights of 3 to 5 feet. Bradow (1986) concludes from observations of survival and relative size that elevations between 1.2 and 1.5 feet NGVD are best for R. mangle in these mitigatión areas. Also, much of the area (except in the center of each site and around the perimeter -- the lowest and highest elevations respectively) has been colonized by Laguncularia racemosa (L.) Gaertn.f. and to a lesser extent A. germinans. Many of the white mangroves are reported to be "eight feet tall or more" (Bradow 1986). The access roads created to allow heavy construction equipment into the mitigation sites were reported to have been colonized as well, especially by L. racemosa.

Also, within this 3.5 year period, the lagoon area comprising the middle of one site, and perhaps channel portions of other sites, have been colonized by the sea grass Rüppia maritima, and clumps of oysters (Crassostrea virginica) in the flushing channels (Bradow 1986). In addition, other animals were abundant in the sites including snails (Littorina angulifera), fiddler crabs (Uca spp.), isopods (Ligia sp.), sheepshead minnows (Cyprinodon variegatus), mullet (Mugil cephalus), and killifish (Fundulus grandis and F. similis).

Bradow (1986) opined that the "young system is providing a valuable benefit to the Naples Bay ecosystem, particularly in regard to biomass production and transport.~~" He further~~ concluded that: "If the primary goal of this project was to create an integrated wetlands/open water system capable of supporting wildlife, then the project was successful".

DESIGN OF THE STUDIES

Definitions:

Sites: The two mitigation areas in which the studies were conducted. Site I is the northernmost (about 3.3 acres) and Site II is the middle (about 7.68 acres in area) of the three original mitigation areas. Site I is roughly circular and Site II is somewhat more elliptical in shape.

Plots: The basic unit of area for study in the mangrove growth, colonization, reproduction, and succession studies in the sites. Twelve plots were established in each of the two study sites. Each plot was 5 x 5 meters in size and was established in a stratified random fashion. Plots were marked using 10 foot long pvc poles driven a couple of feet into the soil at each of the corners.

I. PROJECT DESIGN: Mangrove Growth Study

Our studies focused primarily on the two northern sites because of manpower and funding constraints and ease of access. In both study sites, we established 12, 5 x 5 meter study plots. These were arranged as described below and illustrated in Fig. 1:

"Eastern" Plots E-1, E-2, and E-3: Located in a stratified random manner along the eastern margin of each study site (relatively near the Windstar Development). These plots were also situated closer to the edge of the study sites than the center by placing them at points more than 1/2 the distance from the center of the sites to the edge. Plots were established in areas where the mangrove canopy was five feet or more in height.

"Western" Plots W-1, W-2, and W-3: Located in a stratified random manner along the western margin of each study site (relatively nearer Naples Bay). These plots were also situated closer to the edge of the study sites than the center by placing them at points more than 1/2 the distance from the center of the sites to the edge. Plots were established in areas where the mangrove canopy was five feet or more in height.

"Inner" Plots It-1, It-2, and It-3: Located in a stratified random manner closer the center of each site than the edge by placing them at points less than 1/2 the distance from the center to the margin of the study sites. Plots were established in areas where the mangrove canopy was five feet or more in height.

"Scrub" Plots S-1, S-2, and S-3: Located along the outer margin of the study sites in areas where there was not a generally "closed" canopy and all mangroves were typically less than four feet tall and appeared to possibly be stunted.

In these plots, we selected five (if available) individual trees of each of three species (Rhizophora mangle, Avicennia germinans, and Laguncularia racemosa). For each tree, three branches were tagged with metal numbered tags and marked for evaluation of stem growth, leaf turnover, and plant reproductive activity (fruits and flowers) using latex-based paint sticks. In addition, marked stems were used to assess the frequency of finding cocoons, caterpillars, and snails on the trees. At study initiation, the stems were typically marked at either the most distal leaf scar with both leaves already fallen or at the most distal branch point of the stem (whichever was encountered first moving from apical tip toward the trunk -- usually in R. mangle this was a leaf scar and in A. germinans and L. racemosa was often a branch point).

For the selected trees we measured at, so far, two points in time in the study (Spring-early summer 1989 and Fall 1989):

(1) Tree height (tallest point).

(2) Tree "Diameter at Breast Height (DBH)" - which for these specimens was taken as the point midway between the lowest branch and the highest prop root (R. mangle) or at the very base of the plant next to the sediment (A. germinans and L. racemosa). For red mangroves, the spot where DBH was measured was marked with the paint stick.

(3) Noted whether or not the tree was reproducing.

(4) Survival of the plant.

(4) For each tagged branch we measured:

a. Distance from paint mark to base of apical growing tip.

b. Diameter at a point 1/2 the way along the length in a.

c. The number of leaves.

d. The number of leaf scars.

e. The number of cocoons on leaves.

f. The number of caterpillars on leaves.

g. The number of snails on leaves.

h. The number of flowers (or flower clusters).

i. The number of propagles.

j. The number of reproductive axes (R. mangle)

k. Survival of the branch.

l. Growing apical tip mortality and/or breakage.

m. Number of new branches produced. (All measurements from a - l above were also recorded for new branches)

Preliminary analysis was conducted to determine the degree of "field measuring error" to allow us to assess the repeatability of these measurements and the precision and accuracy of the data.

II. PROJECT DESIGN: Mangrove population densities, colonization and succession study

Definitions:

Mature trees: In all except scrub plots, these were trees over two feet tall (as per typical forestry techniques). In scrub plots this was arbitrarily defined as individuals that had branched more than once.

Seedlings: Were defined as unbranched, germinated and rooted plants. It was not possible to separate true seedlings resulting from de novo colonization events from coppicing in *A. germinans* and *L. racemosa*. However, root-derived shoots are simply another form of colonization of a site.

Saplings: Were defined as plants that had branched once only.

Subplots: Subplots were one meter square sampling areas within the larger 5 x 5 meter study plots described in part I.

We assessed population densities, colonization, and succession in the same study plots described above in part I of this section.

The following mangrove population variables were assessed for all three species of mangroves (unless otherwise indicated) existing in the study sites along the time schedule indicated.

	-------1989 Evaluation-------		
PLANT AGE CATEGORY	June	Sept./Oct.	Nov./Dec.
Mature Trees	x		x
Saplings	x		x
Seedlings	x	x	x
R. mangle propagules	x	x	x

The assessments were conducted in five haphazardly-selected, one meter square subplots within each study plot. In each subplot, all individuals of each age class for each species of mangrove occurring was counted. In addition, during the June 1989 data collection, heights of each mature tree was also measured.

In conjunction with this study, we also assessed the population densities of these same species in the natural forest surrounding the two mitigation study sites. To accomplish this we used either 25 or 5.72 square meter quadrats (depending on the apparent density of seedlings to count). The following mangrove species occurred as members of the canopy in various portions of this forest and were included in our measurements: R. mangle, A. germinans, L. racemosa and Conocarpus erectus L. Three replicate quadrats were established at each of the areas listed below:

	Site I	Site II
Adjacent to the eastern edge of the mitigation site	x	x
Adjacent to the western edge of the mitigation site	x	x
Adjacent to the northern edge of the mitigation site		x

Within each quadrat, we counted the number of trunks of each species and measured the DBH (at a point approximately 1.4 meters above ground level). We also recorded the numbers of seedlings and saplings of each mangrove species, as well as, R. mangle propagules. In addition, we noted any other plant species in the quadrat.

III. PROJECT DESIGN: Spatial coverage of various habitat types

The data on mature plant densities in the study plots (see II above) were combined with low-altitude aerial photography to allow us to estimate the overall aerial coverage and spatial dispersion patterns of different types of habitats ("tall" mangroves, "scrub" mangroves, open water, open dry land, etc.) in the mitigation sites.

IV. PROJECT DESIGN: Percent leaf area lost to herbivory

We evaluated the percent leaf area of R. mangle, A. germinans and L. racemosa entering the food web by grazing. We first determined linear regression relationships for each species between the area of a leaf and the variables leaf length and leaf width for entire, ungrazed leaves. The following allometric relationships were thus determined for ungrazed leaves of each species: (1) Leaf area as a simple linear regression function of leaf length; (2) Leaf area as a simple linear regression function of leaf width (widest point); and (3) leaf area as a multiple linear regression function of both width and length.

From these regression equations, we could calculate the expected area for any leaf for which enough remained ungrazed to permit us to measure either the entire length or width.

We then collected leaves from representative stems of each species from the study sites (not from within our marked plots). For each stem selected, all leaves were collected and the relative distance from the apical tip of the branch to the leaf was recorded (thereby providing the relative ages of the leaves).

For these leaves, the length, width and area were measured. The area measured was then compared to that predicted from regression equations to exist if the leaf had not been grazed upon. The mean difference between the measured and expected areas provided a minimum estimate of the area lost to herbivory. The estimate is minimum because some leaves were so heavily grazed that length and width could not be accurately determined. However, for most leaves, at least one of the two variables could be determined.

Separate assessments were made for "tall" and "stunted" plants (see earlier size descriptions in the definitions included in part I).

V. PROJECT DESIGN: Benthic infaunal invertebrate density monitoring in the lagoon in Site II

Benthic infaunal invertebrate population densities were determined bimonthly in two separate stations in the lagoon, one north of Site II center, and one south of center.

At each station, six replicate 8 cm diameter cores were collected (to a depth of 30 cm) bimonthly. Samples passed through a 0.5 mm mesh screen in the field, relaxed using clove oil, and preserved in formalin (with rose bengal added as a vital stain). Samples were scope sorted and animals identified to the lowest practicable taxon, usually species.

The field portion of this project was begun in July 1989 and will continue until at least a year's dataset is obtained.

VI. PROJECT DESIGN: Sea grass biomass and coverage in the lagoon in Site II

Sea grass samples (*Ruppia maritima* L.) were collected in 8 cm diameter cores. Above sediment and below sediment portions of samples were separated, dried in an oven, and weighed to determine biomass.

Location and size (lengths of major and minor axes) of patches of sea grass were determined to allow calculation of cover and overall biomass.

OTHER OBSERVATIONS

We kept notes on our observations of other wildlife (birds, fish, horseshoe crabs, blue crabs, etc.) seen in the mitigation sites or in the surrounding natural forest. The salient points of these observations will be presented as an appendix to one of the ensuing reports.

In addition, we recorded water depth, water salinity, and salinity of soil water in study sites at various times during the project. These will be presented in subsequent reports as appropriate.

COMMENTS

The studies generated extensive data which will take considerable time to reduce and properly analyze. In addition, we are still gathering data in the field for several of the projects. Thus, the results of our work, and recommendations stemming from the studies, will be provided in a series of reports as analyses are completed.

This report is provided to provide background regarding the studies and as a "end of the year" grant status report for the Department of Environmental Regulation.

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